

WHAT IS CLAIMED IS:

1. A method of drilling a bore hole, comprising:  
alternating between rotary drilling and sliding  
drilling using a steerable drilling motor while a drill  
5 bit remains in substantially continuous contact with a  
bottom of said bore hole, said steerable drilling motor  
being connected by a drill string to a surface drilling  
location.

10 2. The method as claimed in claim 1, further  
comprising:  
rotating said drill string in said bore hole at a  
first speed of rotation.

15 3. The method as claimed in claim 2, further  
comprising:  
advancing said drill string in said bore hole at a  
rate selected to substantially maintain a target  
drilling fluid pressure.

20 4. The method as claimed in claim 1, further  
comprising:  
slowing rotation of said drill string to a second  
speed of rotation.

25 5. The method as claimed in claim 4, further  
comprising:  
stopping rotation of said drill string when said  
steerable motor is at a first selected angle with  
30 respect to a target tool face angle; and  
stopping advancing said drill string.

6. The method as claimed in claim 5, further comprising:

5       advancing said drill string when said steerable  
drilling motor is at a second selected angle with  
respect to said target tool face angle.

7. The method as claimed in claim 6, further comprising:

10       maintaining the selected angle of said steerable  
drilling motor at said target tool face angle.

8. The method as claimed in claim 7, wherein  
maintaining said tool face angle of said steerable  
15       drilling motor at said target tool face angle comprises:

20       adjusting at least one of a rate of release of said  
drill string into said well bore, and an amount of  
rocking said drill string in a first direction and in a  
second direction so as to maintain said drilling fluid  
pressure at a selected value.

9. The method as claimed in claim 7, wherein  
maintaining said tool face angle of said steerable  
drilling motor at said target tool face angle comprises:

25       rotating said drill string.

10. The method as claimed in claim 7, wherein  
maintaining said tool face angle of said steerable  
drilling motor at said target tool face angle comprises:

30       applying a selected torque to said drill string.

11. The method as claimed in claim 7, further comprising:

stopping advancing said drill string; and  
when tool face angle of said steerable drilling  
5 tool moves a selected amount; rotating and advancing  
said drill string.

12. The method as claimed in claim 6, further comprising:

10 commencing rocking said drill string when said  
steerable motor is at a selected angle with respect to a  
target tool face angle.

13. The method as claimed in claim 12, wherein said  
15 rocking comprises:

rotating said drill string in a first direction  
until a first torque magnitude is reached at said  
surface location; and

20 rotating said drill string in a second direction  
opposite said first direction until a second torque  
magnitude is reached at said surface location.

14. The method as claimed in claim 13, wherein said  
first and second torque magnitudes are less than a  
25 torque required to rotate said steerable drilling motor  
in the well bore.

15. The method as claimed in claim 13, further comprising:

30 maintaining the tool face angle of said steerable  
drilling motor at said target tool face angle.

16. The method as claimed in claim 15, wherein maintaining said tool face angle of said steerable drilling motor at said target tool face angle comprises:

5        adjusting at least one of a rate of release of said drill string into said well bore, and the first and the second selected torque magnitudes so as to maintain a drilling fluid pressure at a selected value.

10       17. The method as claimed in claim 15, wherein maintaining said tool face angle of said steerable drilling motor at said target tool face angle comprises:

      adjusting one of said first and second torque magnitudes.

15       18. The method as claimed in claim 17, wherein adjusting one of said first and second magnitudes includes:

20        adjusting said first magnitude if said tool face angle of said steerable drilling motor differs from said target tool face angle in said second direction; and,

      adjusting said second magnitude if said tool face angle of said steerable drilling motor differs from said target tool face angle in said first direction.

25       19. The method as claimed in claim 15, including: stopping advancing said drill string and said rocking; and

30        when tool face angle of said steerable drilling tool moves a selected angle, rotating and advancing said drill string.

20. A method of drilling a bore hole, comprising:

rotating and advancing a drill string having a steerable motor connected thereto in said bore hole, said drill string having a bit at a bottom end thereof, said bit being in contact with a bottom of said well bore, thereby drilling in a rotary mode;

after drilling in said rotary mode, stopping rotation of said drill string and continuing to advance said drill string with said bit in substantially continuous contact with said bottom, thereby drilling in a sliding mode.

21. The method as claimed in claim 20, wherein said rotating and advancing comprises:

rotating said drill string in said bore hole at a first speed of rotation.

22. The method as claimed in claim 21, wherein said rotating and advancing comprises:

advancing said drill string in said bore hole at a rate selected to maintain a target drilling fluid pressure.

23. The method as claimed in claim 22, wherein said stopping said rotation comprises:

slowing rotation of said drill string to a second speed of rotation while maintaining said target drilling fluid pressure differential.

24. The method as claimed in claim 23, wherein said stopping rotation comprises:

stopping rotation of said drill string when said steerable motor is at a first selected angle with respect to a target tool face angle; and,

temporarily stopping advancing said drill string while said bit remains in contact with said bottom.

25. The method as claimed in claim 24, comprising:

advancing said drill string when said steerable drilling motor is at a second selected angle with respect to said target tool face angle.

26. The method as claimed in claim 25, comprising:

maintaining said steerable drilling motor at said target tool face angle.

27. The method as claimed in claim 26, wherein

maintaining said tool face angle of said steerable

drilling motor at said target tool face angle comprises:

adjusting at least one of a rate of release of said drill string and an amount of rocking of said drill string in a first direction and in a second direction so as to maintain said drilling fluid pressure

substantially constant.

28. The method as claimed in claim 26, wherein

maintaining said tool face angle of said steerable

drilling motor at said target tool face angle comprises:

rotating said drill string.

29. The method as claimed in claim 26, wherein maintaining said tool face angle of said steerable drilling motor at said target tool face angle comprises:  
applying a selected torque to said drill string.

30. The method as claimed in claim 20, further comprising:

after drilling in said sliding mode, rotating and advancing said drill string in said bore hole with said bit in substantially continuous contact with said bottom, thereby drilling in said rotary mode.

31. The method as claimed in claim 30, further comprising:

after drilling in said sliding mode, temporarily stopping advancing said drill string with said bit in contact with said bottom; and

rotating and advancing said drill string when said tool face angle of said steerable drilling tool moves a selected angle.

32. The method as claimed in claim 20, further comprising:

stopping rotation of said drill string during said rotary mode when said steerable motor is at a selected angle with respect to a target tool face angle and commencing rocking said drill string in said sliding mode.

33. The method as claimed in claim 32, wherein said rocking comprises:

rotating said drill string in a first direction until a first torque magnitude is reached at said surface location; and,

rotating said drill string in a second direction opposite said first direction until a second torque magnitude is reached at said surface location.

34. The method as claimed in claim 33, wherein said first and second torque magnitudes are less than the torque required to rotate said steerable drilling motor in said well bore.

35. The method as claimed in claim 33, further comprising:

maintaining said steerable drilling motor at said target tool face angle in said sliding mode.

36. The method as claimed in claim 35, wherein maintaining said tool face angle of said steerable drilling motor at said target tool face angle comprises: adjusting at least one of a rate of release of said drill string, said first torque magnitude and said second torque magnitude so as to maintain said drilling fluid pressure differential substantially constant.

37. The method as claimed in claim 35, wherein maintaining said tool face angle of said steerable drilling motor at said target tool face angle comprises:

adjusting one of said first and second torque magnitudes.



38. The method as claimed in claim 37, wherein adjusting one of said first and second magnitudes comprises:

adjusting said first magnitude if said tool face angle of said steerable drilling motor differs from said target tool face angle in said second direction; and, adjusting said second magnitude if said tool face angle of said steerable drilling motor differs from said target tool face angle in said first direction.

39. The method as claimed in claim 32, further comprising:

after drilling in said sliding mode, rotating and advancing said drill string in said bore hole with said bit in substantially continuous contact with said bottom, thereby drilling in said rotary mode.

40. The method as claimed in claim 39, further comprising:

stopping advancing said drill string and said rocking; and

rotating and advancing said drill string when tool face angle of said steerable drilling tool moves a selected angle.

41. A method of drilling a bore hole, comprising:

advancing a drill string having a steerable drilling motor connected thereto in said bore hole, said steerable drilling motor having a tool face angle, said drill string having a bit at a bottom end thereof, said bit being in substantially continuous contact with a

bottom of said well bore, thereby drilling in a sliding mode; and

rotating said drill string and continuing to advance said drill string with said bit in substantially continuous contact with said bottom after drilling in said sliding mode, thereby drilling in a rotary mode.

42. The method as claimed in claim 41, further comprising:

maintaining said steerable drilling motor at a target tool face angle when drilling in said sliding mode.

43. The method as claimed in claim 42, wherein maintaining said tool face angle of said steerable drilling motor at said target tool face angle comprises:

adjusting at least one of a rate of release of said drill string and an amount of rotation of said drill string in a first direction and a second direction so as to maintain a drilling fluid pressure substantially constant.

44. The method as claimed in claim 42, wherein maintaining said steerable drilling motor at said target tool face angle comprises:

rotating said drill string to a selected surface torque value.

45. The method as claimed in claim 42, wherein maintaining said steerable drilling motor at said target tool face angle comprises:

applying a selected torque to said drill string.

46. The method as claimed in claim 41, further comprising:

5 after drilling in said sliding mode, temporarily stopping advancing said drill string with said bit in contact with said bottom; and

rotating and advancing said drill string in said rotary mode when said tool face angle of said steerable  
10 drilling tool moves a selected angle.

47. The method as claimed in claim 41, including:  
rocking said drill string in said sliding mode.

15 48. The method as claimed in claim 47, wherein said rocking comprises:

rotating said drill string in a first direction until a first torque magnitude is reached at said surface location; and

20 rotating said drill string in a second direction opposite said first direction until a second torque magnitude is reached at said surface location.

25 49. The method as claimed in claim 48, wherein said first and second torque magnitudes are less than the torque required to rotate said steerable drilling motor.

50. The method as claimed in claim 48, further comprising:

30 maintaining said steerable drilling motor at said target tool face angle during said sliding mode.

51. The method as claimed in claim 50, wherein maintaining said tool face angle of said steerable drilling motor at said target tool face angle comprises:

5        adjusting at least one of said first torque magnitude and said second torque magnitude so that said drilling fluid pressure differential remains substantially constant.

10    52. The method as claimed in claim 50, wherein maintaining said steerable drilling motor at said target tool face angle comprises:

      adjusting one of said first and second torque magnitudes.

15    53. The method as claimed in claim 52, wherein adjusting one of said first and second magnitudes comprises:

20        adjusting said first magnitude if said tool face angle of said steerable drilling motor differs from said target tool face angle in said second direction; and,

      adjusting said second magnitude if said tool face angle of said steerable drilling motor differs from said target tool face angle in said first direction.

25    54. The method as claimed in claim 48, including:  
      temporarily stopping advancing said drill string;  
      stopping said rocking routine; and  
      rotating and advancing said drill string in said  
30    rotary mode when tool face angle of said steerable drilling tool moves a selected angle.

55. A method of directional drilling, which comprises:

(a) orienting a steerable drilling motor at a target tool face angle, said steerable drilling motor being connected by a drill string to a surface drilling location;

(b) rocking said drill string by:

(i) rotating said drill string at said surface location in a first direction until a first torque magnitude is reached at said surface location substantially without changing a tool face angle of said said steerable drilling motor; and

(ii) rotating said drill string at said surface location in a second direction opposite said first direction until a second torque magnitude is reached without changing the face angle of said steerable drilling motor; and

(c) maintaining the tool face angle of said steerable drilling motor at said target tool face angle by adjusting at least one of said first and second torque magnitudes for least one drill string rotation in the first and second direction.

56. The method as claimed in claim 55, wherein adjusting one of said first and second magnitudes comprises:

adjusting said first magnitude if said tool face angle of said steerable drilling motor differs from said target tool face angle in said second direction; and,

adjusting said second magnitude if said tool face angle of said steerable drilling motor differs from said target tool face angle in said first direction.

5 57. The method as claimed in claim 55 wherein adjusting one of said first and second magnitudes comprises:

measuring a drilling fluid pressure; and  
adjusting at least one of the first and second magnitudes to maintain the drilling fluid pressure  
10 substantially constant.

58. A directional drilling system, which comprises:

a steerable drilling motor;  
a steering tool coupled to said steerable drilling  
15 motor, said steering tool being adapted to produce a tool face angle signal;

a drill string coupled to said steerable drilling motor;

a drill string torque sensor coupled to said drill  
20 string, said torque sensor being adapted to produce a drill string torque signal;

means for rotating said drill string at a surface location;

a controller for operating said rotating means to  
25 rotate said drill string cyclically back and forth in a first direction until a first torque magnitude is reached and then in a second direction opposite said first direction until a second torque magnitude is reached; and,

a bump control for adjusting at least one of said first and second torque magnitudes for at least one cycle.

5 59. The system as claimed in claim 58, wherein said bump control includes for increasing said first and second magnitudes by user specified amounts.

10 60. A method for directional drilling, comprising:  
advancing a drill string including a bit and a drilling motor thereon along a bore hole, the drilling motor oriented at a selected tool face angle;  
rotating the drill string in a first direction until a first torque magnitude is reached;  
15 rotating the drill string in a second direction opposite to the first direction until a second torque magnitude is reached;  
repeating rotating the drill string in the first direction to a torque value increased by a selected  
20 amount above the previous torque magnitude in the first direction; and  
repeating the rotating the drill string in the second direction, rotating again in the first direction and increasing the torque until the drill string rotates  
25 substantially continuously in the first direction.

61. The method of claim 60 further comprising decreasing the torque in the second direction by a selected amount each time the drill string is rotated in  
30 the second direction.

62. The method of claim 60 further comprising reducing a rate of release of the drill string into the bore hole prior to increasing the torque in the firsts direction.